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Our overall goal in this research effort has been to reduce the time and cost of constructing embedded knowledge-based systems that must handle uncertainty in information in a rigorous manner. Our fundamental approach actively assists subject-matter experts in organizing their knowledge inclusive of uncertainty to build such embedded systems in a consistent and correct as well as effective fashion. We pursued this by carefully examining the nature of uncertainty and information semantics and developing intelligent tools for verification and validation that provides assistance to the subject-matter expert in constructing their knowledge-based systems. We have developed a prototype environment for constructing Bayesian Knowledge-Bases called PESKI.

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## **AFOSR Project Final Report**

**Project Title:** Verification and Validation of Embedded Knowledge-Based Software Systems

**PI:** Eugene Santos Jr., University of Connecticut

**AFOSR Grant No.** F49620-99-1-0059

**AFOSR PM:** Dr. Robert Herklotz

### **Final Project Summary**

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### **Major Accomplishments**

- Completed formulation of Bayesian Knowledge-Bases as basis of representing uncertainty and proved it's generality through subsumption of Bayesian networks and probabilistic consistency.
- Developed a novel representation that unified probabilistic uncertainty and time.
- Defined structural incompleteness and integrated tool for managing incompleteness into PESKI.
- Developed new algorithm for reasoning under uncertainty based on randomized algorithms and reinforcement learning.
- We have developed a novel knowledge structure that can express common relationships among evidence for a conclusion via an N-of-K relation and can be constructed automatically. This relation allows the system to hide much of the structure necessary to guarantee the internal consistency of the knowledge-base. Hiding such implementation details from the expert user allows the expert to better concentrate on knowledge acquisition and validation. Our relation also captures probabilistic uncertainty in a provably correct manner.
- Formally proved the semantics of Bayesian Knowledge-Bases to provide a natural an implicit method for flexibly acquiring knowledge. By maximizing the ease with which to incorporate new knowledge in a simple if-then format while automatically maintaining consistency in the knowledge base is critical to the success of a knowledge acquisition framework.
- Finalized PESKI system for dissemination to the research community.

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**Publications** [ 7 journal articles, 1 book chapter, 16 conference papers ]

[ The publications below were supported in full or in part by this project. ]

1. Santos, Eugene, Jr. and Santos, Eugene S., "A Framework for Building Knowledge-Bases Under Uncertainty," *Journal of Experimental and Theoretical Artificial Intelligence* 11, 265-286, 1999.
2. Santos, Eugene, Jr. and Young, Joel D., "Probabilistic Temporal Networks: A unified framework for reasoning with Time and Uncertainty," *International Journal of Approximate Reasoning* 20, 263-291, 1999.
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10. Nguyen, Hien, Saba, G. Mitchell, Santos, Eugene, Jr., and Brown, Scott M., "Active User Interface in a Knowledge Discovery and Retrieval System," Proceedings of the 2000 International Conference on Artificial Intelligence (IC-AI 2000), Las Vegas, NV, 2000.

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14. Santos, Eugene, Jr., "Verification and Validation of Knowledge-Bases Under Uncertainty," *Data and Knowledge Engineering* 37, 307-329, 2001.
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16. Santos, Eunice E. and Santos, Eugene, Jr., "Effective and Efficient Caching in Genetic Algorithms," *International Journal of Artificial Intelligence Tools* 10(1-2), 273-301, 2001.
17. Lee, Jung-Jin, McCartney, Robert, and Santos, Eugene, Jr., "Learning and Predicting User Behavior for Particular Resource Use," Proceedings of the 14th International FLAIRS Conference, 177-181, Orlando, FL, 2001.
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19. Santos, Eugene, Jr., Santos, Eugene S., and Shimony, Solomon Eyal, "Semantics and Knowledge Acquisition in Bayesian Knowledge-Bases," Proceedings of the 15th International FLAIRS Conference, 524-528, Pensacola, FL, 2002.
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Proceedings of the 11th Conference on Computer Generated Forces and Behavioral Representation, 535-542, Orlando, FL, 2002.

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